DARPA R&D Status Report

DARPA Order No.:

Program Code No.:

Contractor: General Electric Corporate Research and Development

Contract Amount: $2,582,405

Contract No.: N00014-96-C0145

Effective Date of Contract: June 26, 1996

Expiration of Contract: June 30, 2000

Principal Investigator: James Cella

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Short Title of Work: Non-toxic, Self Cleaning Silicone Foul Release Coatings

Reporting Period: January through March 1998

Description of Progress:

Task 1: Design, Synthesis and Testing of Foul Release Paints With Improved Antifouling and Release Properties

Task 1.1: Design, Synthesis and Testing of Foul Release Paints (GE-CRD)

Data collection continues on about 30 screening panels at FIT and about 70 panels at MMRTS. A second set of downselect panels have been deployed at FIT, Bridger Scientific, University of Hawaii, and SUNY Buffalo.

Task 1.1.1: Quantitative Foul Release Performance of New Materials (FIT)

Static Immersion of Test Coatings

Screening panels (4"x10") for short term evaluation and downselect panels (10"x12") for long term appraisal continue to be monitored at the FIT static immersion site. These are caged to prevent loss of barnacles by fish predation. All current data has been processed and presented at a working meeting held in late March.

Hydrodynamic Foul Release / Skin Friction Measurements

A total of 14 downselect panels were immersed (9/9/97) specifically to address skin friction and hydrodynamic foul release as measured by an instrumented foil. Barnacle adhesion measurements have been obtained for the panels and foil testing has been accomplished on three of the panels. The maximum velocity reached on these tests was 14 knots. The speed was limited due to undue flexing of the support frame. This has since been strengthened and testing will continue as soon as the weather co-operates.

Video Demonstration

A video has been prepared and circulated to demonstrate the Hydrodynamic Foul Release / Skin Friction Measurements.

Task 1.1.2: Field Exposure Testing (Bridger Scientific)

Performance data for the downselect test matrix were reviewed in the December, 1997 quarterly report and presented at the 27 March 1998 program meeting at Florida Institute of Technology. Although some variations in fouling coverage and foul release were observed, the relative ranking for test coating formulations is consistent between the two northeastern test sites. In addition, results from statistical analysis by the University of Hawaii indicate there is a good correlation with the other field test locations. Coatings which are performing well are series 5 and 13. Formulations in the lowest ranking group are in series 3, 10 and 11 (front). A preliminary inspection of all test panels was performed in March 1998. A fouling rating was not possible at this time since panels at both locations generally exhibited only attached sediment/slime of varying densities. Some incipient barnacle fouling was observed on panels in the higher velocity zone at the Manchester Street site. Other attached hard foulers were larger and may be translocated individuals. Foul Release measurements for biological slimes again showed some intra-panel variation. Although material was generally less dense on the back side of the panels, it is more adherent. Due to space limitations, panels in series 3, 10, and 11 will be removed during the second week of April 1998 and replaced with panels in the second downselect matrix. Panels which were damaged during the winter will also be removed; all will be forwarded to Dr. Anne Meyer for post exposure failure analyses. Monthly inspections of the downselect and preliminary test matrices will resume in May 1998 at the onset of the fouling season.

Task 1.2: Validation Testing (NSWC, University of Hawaii)

Bilge Keel Panels

Bilge keel panel were installed on the USS JOHN PAUL JONES in March 1998. Four test coatings were exposed (Series 5, 9, 13, and 12). For each test system, four test panels

were prepared. Two were installed on each side of the ship. Annual evaluations, based on ship availability are planned.

Validation Testing at the University of Hawaii

After 185 days of exposure, several of the panel treatments had become heavily fouled. The overall level of fouling increased dramatically over the December inspection. Through February the most common organisms present on the test panels were bivalve molluscs. Tubeworms (with calcareous tubes) and sponges were also common but at much lower levels of coverage than the bivalves. All panels, including BRA, were fouled to some extent, at least around the edges. Panel treatment 6 was the most heavily fouled, with a mean (four replicates) of 80% of the surface encrusted. Panels 1, 2, 3, 4, and 11 (back and front) supported macrofouling on greater than 40% of their surface. Panels 8, 9 and 10 were less heavily fouled, with mean coverage by macrofoulers of from 20-40%. The remaining treatments (5, 7, 12, 13) were only lightly fouled. In all cases increases in extent of fouling were mainly due to continued settlement and growth of hard foulers. Coverage of soft fouling organisms showed no relationship to coating type. We observed no damage or coating failures on any of the panels.

Additional data on adhesion of Hydroides elegans and oysters was collected on January 14, 1998. Temporal variation is present in the adhesion measurements taken for both types of hard fouling, however, that variation does not appear to show a trend over time, nor does it appear to be related to coating treatment. There remained significant differences among the panels in force required to remove Hydroides (one-way ANOVA, $F = 13.41$, $p \pounds 0.0001$, $df = 13, 267$).

Forces required to remove bivalve mollusks from the panels were generally higher than those required to remove Hydroides. We observed significant differences among the panels in attachment strengths of oysters (one-way ANOVA, $F = 12.06$, $p \pounds 0.0001$, $df = 12, 145$). Panels that performed well in terms of removal of tubeworms also performed well in tests on oysters; the rank correlation between force to remove Hydroides and force to remove oysters was positive and significant ($r_{sp} = 0.742$, $p < 0.004$).

Panels 4, 7 and 13 exhibited exceptional performance in the water jet test, with all slimes being removed from the coating surface at a water jet pressure of 75 psi or lower. Bulk slimes cleaned from all of the remaining panels at pressures of 25 - 75 psi, while adherent slimes could be removed from some of these panels at pressures of 75 - 200 psi. The adherent slimes, however, could not be removed at pressures of 200 psi from some examples of panel treatments 3, 8, 10 and 11 (back and front). Soft fouling could also be removed from all of the treatments using the water jet. Hard fouling, however, could not be cleaned from the majority of the panels. This was probably a function of the continued growth of oysters attached to these panels. All fouling (hard, soft and slime) could be removed from panel treatment 7 with the water jet.

Task 2: Optimize Coating Physical and Application Properties

Task 2.1 Physical Property Optimization (GE)

Task 2.2.1 Cleanability of Foul Release Coatings (SUNY Buffalo)

In response to an action item from the October 1997 program meeting, a subset of surface analysis data was forwarded to Dr. Eric Holm for statistical analysis. The downselect set #1 panels at Dunkirk site were evaluated in January and the replicate set of panels at the Medina site were evaluated in March. The panels at the Dunkirk site had been damaged during the winter, and the racks containing the panels were swinging freely. The racks and panels were removed from the Dunkirk site to exploit the analytical opportunity for examination of the damaged coatings. Pre-exposure surface analyses and brush abrasion testing on Downselect set #2 panels were initiated.

Task 3: Environmental Impact and Toxicological Testing

Task 3.1: Environmental Impact (GE)

The leach rate of three ^{14}C labeled silicone oils from RTV 11 is being monitored. Two of the oils, a PDMS and a polydimethyldiphenylsiloxane (PDMDPS), were retained by the RTV at levels in excess of 99% of their initial loading in both fresh water and salt water fish tanks after 11 and 10 months, respectively. The third oil, a carbinol terminated PDMS, has been reduced to approximately 60% of its original loading after 5 months, however, most of that loss was observed in the first two months.

Task 3.2: Toxicological Studies (NSWC, NCCOSC)

This quarter's activities focused on finishing the toxicity testing of the nine coatings sent to SPAWARSYS Center, San Diego, for evaluation. All nine coatings were tested for toxicity with leachates made from the films. These tests included the 4 day Mysid Shrimp survival test, the 4 day minnow survival test and the 4 day chain diatom fluorescence-biomass test. Leachates from all coatings were analyzed for dibutyltin which may have had a contributing effect in some of the toxicity tests. The least toxic coatings were series 5 and 8 and the most toxic was series 10.

Change in Key Personnel:
None

Summary of Substantive Information Derived from Special Events

GE/DARPA Program Meeting, Melbourne, FL, 26-28 March 1998. The March meeting was hosted by FIT at the Quality Suites Hotel, Melbourne. The contents of the two day meeting are contained in minutes prepared by Deborah Wiebe, Bridger Scientific, Inc.

The meeting was concluded by a visit to Harbor Branch for a demonstration of skin friction measurements made in the water tunnel.

A presentation was given at the ACS meeting in Dallas on April 1 entitled "Advances in Nontoxic Silicone Biofouling Release Coatings," T.B. Burnell, J.C. Carpenter, K.M. Carroll, J.A. Serth-Guzzo, J. Stein, K.E. Truby, G. Swain, C. Kavanaugh and D. Wiebe. A presentation was given at the Silicones in Coatings II Conference in Orlando, Florida on March 25 entitled "Advances in Nontoxic Silicone Foul Release Coatings," J. Carpenter, T. Burnell, K. Carroll, J. Serth-Guzzo, J. Stein and K. Truby.

Problems Encountered and/or Anticipated:

None.

Action Required by the Government:

None.

Fiscal Status:

Project Cost:	$1,006,426
Cost Share:	(230,395)
Net to ONR/DARPA:	$722,238

2QFY98 DARPA QUARTERLY REPORT

DARPA Order No.: ONR FY96PR NUMBER 96PR04639-01
Program Code No.:

Contractor: NAVAL SURFACE WARFARE CENTER, CARDEROCK DIVISION
Contract Amount: PLANNED FY 98 FUNDS - $163,174.00
Contract No.: FY98 RECEIVED 3/18/98

Effective date of contract: ANTICIPATED FY98 WORK REQUEST START DATE - 1/98
Expiration Date of Contract: ANTICIPATED FY 98 WORK REQUEST COMPLETION DATE - 9/98

Principal Investigator: KAREN M. POOLE
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Short Title of Work: NON-TOXIC, SELF-CLEANING SILICONE FR COATINGS

Reporting Period: 2QFY98 (1/98 - 3/98)

Description of Progress: Bilge keel test panels were installed on USS JOHN PAUL JONES (DDG 53) in March 1998. Four test coating systems were exposed. The four test coating systems are: (1) J501 with 10% SF69 / RTV11 with 10% DMSC15, (2) J501 with 10% SF69 / RTV11 with DBE224 and 5% SF1154, (3) J501 with 10% SF69 and Seanine 211 / RTV11 with 10% DMSC15, and (4) J501 with 10% SF69 and CMS222 / RTV11. For each test system, four test panels were prepared. Two were installed on each side of the ship. Annual evaluations, based on ship availability, are planned. NCCOSC focused on completing toxicity testing of nine test coatings. Overall, the most toxic coating to all test organisms was RTV11 + 10% ablative carbinol. The least toxic coatings were RTV11 + 10% DMSC15 and RTV11 + 10% ALT251. All test results were presented at the DARPA-GE meeting held March 27, 1998 in Melbourne, Florida. University of Hawaii performed statistical analysis on laboratory and field data. Statistical analysis supported selection of top performing coatings as well as confirmation of poor performers.

Change in Key Personnel: NONE
Summary of Substantive Information Derived from Special Events: NONE
Problems Encountered and/or Anticipated: NONE

Action Required by the Government: NONE

Fiscal Status:

(1) Amount currently provided on contract:
FY98 FUNDS - $163,174.00
(2) Expenditures and commitments to date:
FY96 $70,484.48
FY97 $128,174.50
(3) Funds required to complete the work:
$154,831.80